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Human influence on the record-breaking cold event in

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21 Capsule summary

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23 Anthropogenic influences are estimated to have reduced the likelihood of an extreme
24 cold event in mid-winter with the intensity equal to or stronger than the record of
25 2016 in Eastern China by about 2/3.

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Introduction

A strong cold surge occurred during 21st–25th January 2016 affecting most areas of China, especially Eastern China (Fig. 1a). Daily mean temperatures dropped by up to 10–18 °C within this event at individual stations in this region (CMA 2017) and broke daily minimum temperature (T_{min}) records at many stations (Fig. 1b). The area averaged anomaly of T_{min} over the region (20–44°N, 100–124°E) for this pentad was –4 °C (–2.2 standard deviations) relative to the 1961–1990 normal. This was the lowest temperature recorded, for the 21st–25th January, since modern meteorological observations started in 1960 (Fig. 1c). According to press reports (CMA 2017), 1.18 billion people were in the area where daily mean temperatures fell by more than 6 °C within this event. On 24th January, the snowline even reached Guangzhou and the Pearl River Delta in southern China. This was the lowest latitude recorded since 1951. A sharp temperature drop, low temperatures and associated freezing rain and snow caused widespread disruptions to transport, power supply and public services, and damage to agriculture in southern China (<http://mt.sohu.com/20160210/n437184257.shtml> - last accessed 19th March 2017).

Cold extremes have been gained wide attention in many parts of mid-latitude Eurasia and North America in recent years (e.g. Mori et al. 2014; Trenary et al. 2015; McCusker et al. 2016). It is controversial whether they are related to Arctic warming. Some studies suggested that greenhouse-gas-induced global and Arctic warming may enhance the meandering of the jet stream thus increase the probability of cold extremes in certain regions (Francis and Vavrus, 2015), and that the Arctic warming in the Barents-Kara Seas is closely connected to the cooling in Eastern Asia (Kug et al. 2015) and robust Arctic sea-ice influence on recent increases in Eurasian cold winters (Mori et al. 2015). However, other studies have suggested that the Arctic warming

does not cause mid-latitude cooling (e.g, McCusker et al. 2016; Sun et al. 2016).

Given the impact of this cold event in China and the controversy whether Asian mid-latitude cold surges are becoming more likely as a consequence of Arctic warming, it is compelling to investigate how much anthropogenic forcing agents have affected the probability of cold events with an intensity equal to or larger than the January 2016 extreme event. We use the Met Office Hadley Centre system for Attribution of extreme weather and Climate Events (ACE; Christidis et al. 2013; Burke and Stott, 2017) and station observations to investigate the effect of anthropogenic forcings on the likelihood of such a cold event.

Data

We used observational data for T_{min} from 744 national Reference Climatic and Basic Meteorological Stations from the China National Meteorological Information Centre for the period 1960–2016. From 1960 to 2013, the updated temperature dataset developed by Li et al. (2015) is used. This dataset was homogenized using the Multiple Analysis of Series for Homogenization (MASH) method (Szentimrey, 1999) and was improved in terms of physical consistency among diurnal temperature records (Li et al. 2015), such that the temperature observations were quality-controlled and adjusted for most non-climatic biases due to the changes in the local observing system, such as station relocation. After 2013, it is updated directly from those stations that have continuous records to January 2016.

We used simulations of the Hadley Centre Global Environmental Model version 3 Global Atmosphere 6.0 (HadGEM3-GA6) (Walters et al. 2017) at N216 resolution. Daily outputs of T_{min} at approximately $0.56^{\circ} \times 0.83^{\circ}$ horizontal resolution are used.

members of the historical (all forcing) 1961–1990 period (hereafter histClim) are compared with observations to estimate the model bias. Two ensembles of 525 members with and without anthropogenic forcings are provided for January 2016 to estimate the risk of such a cold event. One of these ensembles (hereafter histALL) uses historical anthropogenic and natural forcings, and is an extension of the previous 15 member histClim runs. The other ensemble (hereafter histNAT) uses natural forcings only and is a continuation of a historical natural ensemble of 15 members, complementary to the histClim runs. Beyond the initial conditions of this continuation, the only difference between each of the 525 members in these experiments is the stochastic physics seed, and they are therefore considered equivalent. The boundary conditions for the histNAT experiments (see Supplementary material) are the same as in previous experiments using an earlier version of Met Office attribution system (Christidis et al. 2013).

Methods

For each station, the observed daily T_{min} anomaly relative to 1961–1990 was calculated, from which the pentad-mean T_{min} anomaly for 21st–25th January (hereafter PT_{min}) of each year was computed. These PT_{min} were gridded into $2^{\circ} \times 2^{\circ}$ grid boxes for the region (20° – 44° N, 100° – 124° E) by simply averaging the available station data within a $2^{\circ} \times 2^{\circ}$ grid box. This region was chosen because the PT_{min} had a large negative anomaly in most stations of this region (Fig. 1a). We also calculated the regional average winter (December-January-February, DJF) T_{min} anomalies over the region.

To make observations and simulations comparable the following steps were

adopted. (1) For both histALL and histNAT ensembles, daily anomalies (relative to 1961–90 normal for histClim) were computed removing any constant model bias. (2) PT_{min} for 2016 in histALL and histNAT runs were calculated and a land-sea mask applied. (3) These masked anomalies were regridded to the same $2^\circ \times 2^\circ$ grid boxes as the observations using linear interpolation and masked by the observational gridded data. (4) Gridded observations were then masked by this simulated data. (5) The area-weighted average PT_{min} of both the observations (Fig. 1c) and the 525 histALL and histNAT runs were then computed.

To estimate the attributable risk (Stott et al. 2004; Stott et al. 2016) of such an extreme cold event in mid-winter, area-weighted average T_{min} anomalies of 9 non-overlapping pentads from the coldest period in the climatology (1st January to 15th February), from the 525 histALL and histNAT runs were calculated and fitted to probability distribution functions (PDFs). Goodness-of-fit was tested for Gaussian and generalized extreme value (GEV) distributions. The GEV fit was found to be the most appropriate (Fig. S1) and return periods of an event like the one in 2016 were estimated from this GEV fit. The shape, scale, and location parameters of the GEV fit for histALL (histNAT) runs are -0.28, 2.35, and -0.21 (-0.31, 2.25, and -1.39), respectively.

Results

Figure 1a shows that during this extreme cold event, most stations in Eastern China recorded negative PT_{min} , with the largest negative anomalies below -4°C . The PT_{min} broke the historical low temperature records for the same pentad at more than twenty stations and many more recorded the second and third coldest pentad since

1960 (Fig. 1b). The linear trend in the regional average PT_{min} (hereafter $RAPT_{min}$) (Fig. 1c) is $0.078^{\circ}\text{C}/\text{decade}$ with 95% confidence interval of $(-0.26, 0.45)$, which is not statistically significant. This trend slope and significance testing is based on the nonparametric Sen's slope and Mann-Kendall test taking into account the first-order autocorrelation estimated by an iterative method (Wang and Swail, 2001, hereafter WS2001). The 2016 $RAPT_{min}$ is the coldest 21st–25th January, in the record which started 1960, beating the previous record in 1984 (Fig. 1c). Figure 1d shows that this cold event occurred in a background of the warmest winter T_{min} since 1960, showing a warming trend of $0.56 (-0.05, 1.0054)^{\circ}\text{C}/\text{decade}$ estimated also by WS2001, and that El Niño tends to be associated with warm winters (four-out-of-five El Niño years since 1982).

Figure 2a shows an overall mean shift toward warmer anomalies in histALL relative to histNAT indicating that human influences have reduced the risk of extreme cold event. To estimate the attributable risk ratio, we defined a threshold of -4°C based on the observed $RAPT_{min}$ for 2016. The probability (P_0) of an event equal to or colder than this threshold in mid-winter in histNAT is 6.8%, whereas in histALL (P_1) it is only 2.3%. The risk ratio (P_1/P_0) is approximately 34%, which suggests that human influences have reduced the risk of such an extreme cold event by about 66%. We estimated the uncertainty of P_1/P_0 by resampling the PDF 1000 times (Pall et al. 2011). Results show that P_1/P_0 lies between 31.1% and 37.8% (one standard deviation), suggesting that human influences reduced the probability of such a cold event by approximately two thirds (Fig. 2b). The estimated return period of $RAPT_{min}$ like January 2016 is one-in-15-years with only natural forcings while it is extended to one-in-43 years with anthropogenic forcings (Fig. 2c).

Conclusions and discussion

Cold winters in China are expected to become rarer in a warming climate. By employing high quality station observations and model simulations, we estimate that anthropogenic influences have reduced the occurrence probability of an extreme cold event with the intensity equal to or stronger than the record in 2016 by approximately 2/3. Conversely, if there were no anthropogenic influences, the probability of an extreme cold pentad in 2016 would be more than doubled. The return period of such a record cold event is estimated to have been extended by about 28 years due to human influences. Our results are in line with McCusker et al. (2016) and Sun et al. (2016) and agree with Trenary et al. (2015) that despite severe cold surges and record-breaking extreme cold-day occurrences during 2016, winters have become warmer. Our results also imply that even under human-induced warming extreme cold events can still occur as a result of natural variability, such as Arctic Oscillation, which was believed to be responsible for the reporting event (Cheung et al. 2016).

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References

- Allen, M., 2003: Liability for climate change, *Nature*, 421(6926), 891–892.
- Burke, C. and Stott, P., 2017: Impact of anthropogenic climate change on the East Asian summer monsoon, *J. Clim.*, DOI: 10.1175/JCLI-D-16-0892.1
- Cheung, H. H. N., W. Zhou, M. Y. T. Leung, C. M. Shun, S.M. Lee, and H. W. Tong, 2016: A strong phase reversal of the Arctic Oscillation in midwinter 2015/2016: Role of the stratospheric polar vortex and tropospheric blocking, *J. Geophys. Res. Atmos.*, 121, 13,443–13,457, doi:10.1002/2016JD025288.
- Christidis, N., P. A. Stott, A. A. Scaife, A. Arribas, G. S. Jones, D. Copsey, J. R. Knight, and W. J. Tennant, 2013: A new HadGEM3-A-based system for attribution of weather- and climate-related extreme events, *J. Clim.*, 26(9): 2756–2783, doi:10.1175/JCLI-D-12-00169.1
- CMA, 2017: *China Climate Bulletin 2016*. China Meteorological Administration
- Francis, J. A., and S. J. Vavrus, 2015: Evidence for a wavier jet stream in response to rapid Arctic warming, *Environ. Res. Lett.*, 10, doi:10.1088/1748-9326/10/1/014005.
- Kug, J.-S., J.-H. Jeong, Y.-S. Jang, B.-M. Kim, C. K. Folland, S.-K. Min, and S.-W. Son, 2015: Two distinct influences of Arctic warming on cold winters over North America and East Asia, *Nat. Geosci.*, doi:10.1038/ngeo2517.
- Li, Z., Z. W. Yan, and H. Y. Wu, 2015: Updated homogenized Chinese temperature series with physical consistency. *Atmos. Oceanic. Sci. Lett.*, 8: 17–22, doi:10.3878/AOSL20140062
- McCusker, K.E., J.C. Fyfe, and M. Sigmond, 2016: Twenty-five winters of

198 unexpected Eurasian cooling unlikely due to Arctic sea-ice loss. *Nat. Geosci.*,
199 9:838-842

200 Mori M., Watanabe M., Shiogama H., Inoue J. and Kimoto M., 2014: Robust Arctic
201 sea-ice influence on the frequent Eurasian cold winters in past decades. *Nat.*
202 *Geosci.*, DOI: 10.1038/NGEO2277

203 Pall, P., T. Aina, D. A. Stone, P. A. Stott, T. Nozawa, A. G. J. Hilberts, D. Lohmann,
204 and M. R. Allen, 2011: Anthropogenic greenhouse gas contribution to flood risk
205 in England and Wales in autumn 2000. *Nature*, 470, 382–386.

206 Stott P A, Christidis N, Otto F E L, et al., 2016: Attribution of extreme weather and
207 climate - related events. *Wiley Interdisciplinary Reviews: Climate Change*, 7(1):
208 23-41.

209 Stott, P. A., D. A. Stone, and M. R. Allen, 2004: Human contribution to the European
210 heatwave of 2003, *Nature*, 432(7017), 610–614, doi:10.1038/nature03089.

211 Sun, L., J. Perlwitz, and M. Hoerling, 2016: What caused the recent "warm Arctic,
212 cold continents" trend pattern in winter temperatures?, *Geophys. Res. Lett.*, 43,
213 5345-5352, doi:10.1002/2016GL069024.

214 Szentimrey, T. 1999: Multiple analysis of series for homogenization
215 (MASH)[C]//*Proceedings of the 2nd Seminar for Homogenization of Surface*
216 *Climatological Data*. Budapest, Hungary: WMO, 27-46

217 Trenary L., DelSole T., Tippett M. K., and Doty B., 2016: Extreme Eastern U.S.
218 winter of 2015 not symptomatic of climate change, *Bulletin of the American*
219 *Meteorological Society*, DOI:10.1175/BAMS-D-16-0156.1

220 Walters, D., Boutle, I., Brooks, M., Melvin, T., Stratton, R., Vosper, S., Wells, H.,

221 Williams, K., Wood, N., Allen, T., Bushell, A., Copsey, D., Earnshaw, P.,
 222 Edwards, J., Gross, M., Hardiman, S., Harris, C., Heming, J., Klingaman, N.,
 223 Levine, R., Manners, J., Martin, G., Milton, S., Mittermaier, M., Morcrette, C.,
 224 Riddick, T., Roberts, M., Sanchez, C., Selwood, P., Stirling, A., Smith, C., Suri,
 225 D., Tennant, W., Vidale, P. L., Wilkinson, J., Willett, M., Woolnough, S., and
 226 Xavier, P., 2017: The Met Office Unified Model Global Atmosphere 6.0/6.1 and
 227 JULES Global Land 6.0/6.1 configurations, *Geosci. Model Dev.*, 10, 1487-1520,
 228 doi:10.5194/gmd-10-1487-2017.

229 Wang, X. L., and V. R. Swail, 2001: Changes of extreme wave heights in Northern
 230 Hemisphere oceans and related atmospheric circulation regimes. *J. Climate*, 14,
 231 2204–2221.

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Figure Caption List

FIG. 1. (a) Observed pentad T_{min} anomalies (relative to the 1961–1990 climatology) for 21st–25th January, 2016. Dashed box indicates the study region (20–44°N, 100–124°E); (b) Coloured dots represent the stations that in 2016 recorded the coldest (red), the second coldest (green) and third coldest (blue) pentad T_{min} for any 21st–25th January since 1960. (c) Time series of the area-weighted average 21st–25th pentad T_{min} anomaly over the study region for the period 1960–2016. Red line shows linear trend of 0.078°C/decade. (d) Averaged winter T_{min} anomalies and the corresponding linear trend over 1960/61–2015/16 in the target region. Labelled dots show El Niño years.

FIG. 2. (a) GEV distribution fit to the 9×525 regional average pentad T_{min} anomalies during mid-winter 2016 in Eastern China from histALL simulations (red line; with anthropogenic and natural forcings) and that from histNAT simulations (green line; only with natural forcings). The dashed line indicates the threshold, which is the regional average pentad T_{min} anomaly of 21st–25th January 2016 in the observations. (b) Uncertainty in the attributable risk ratio of such an extreme cold event due to anthropogenic influences. Dash lines indicate one standard deviation. (c) Return period of extreme cold event with the intensity equal or larger than the extreme cold event of January 2016 in Eastern China in the histALL (red line) and histNAT simulations (green line). The black dashed line indicates the threshold used in (a).

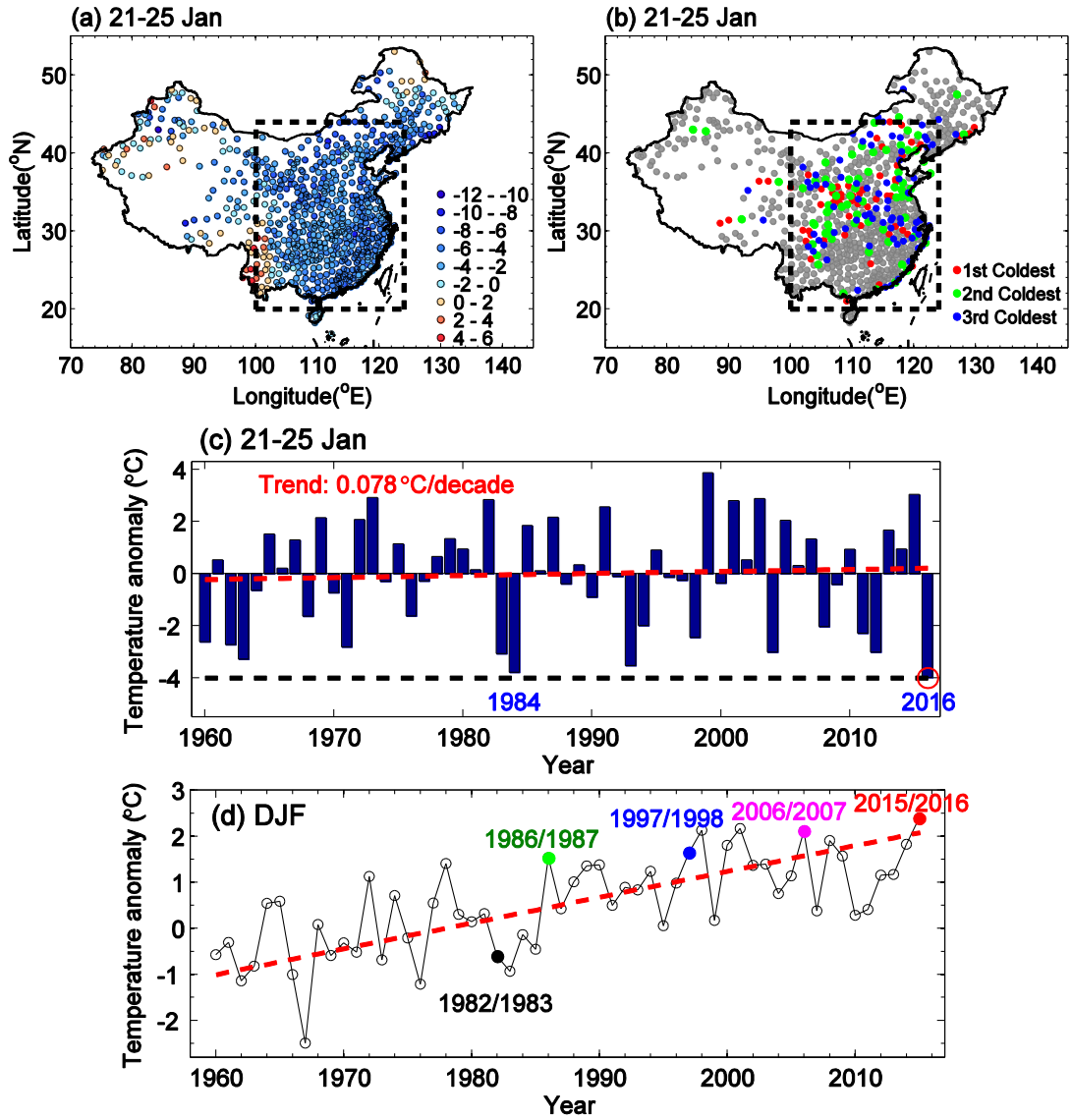


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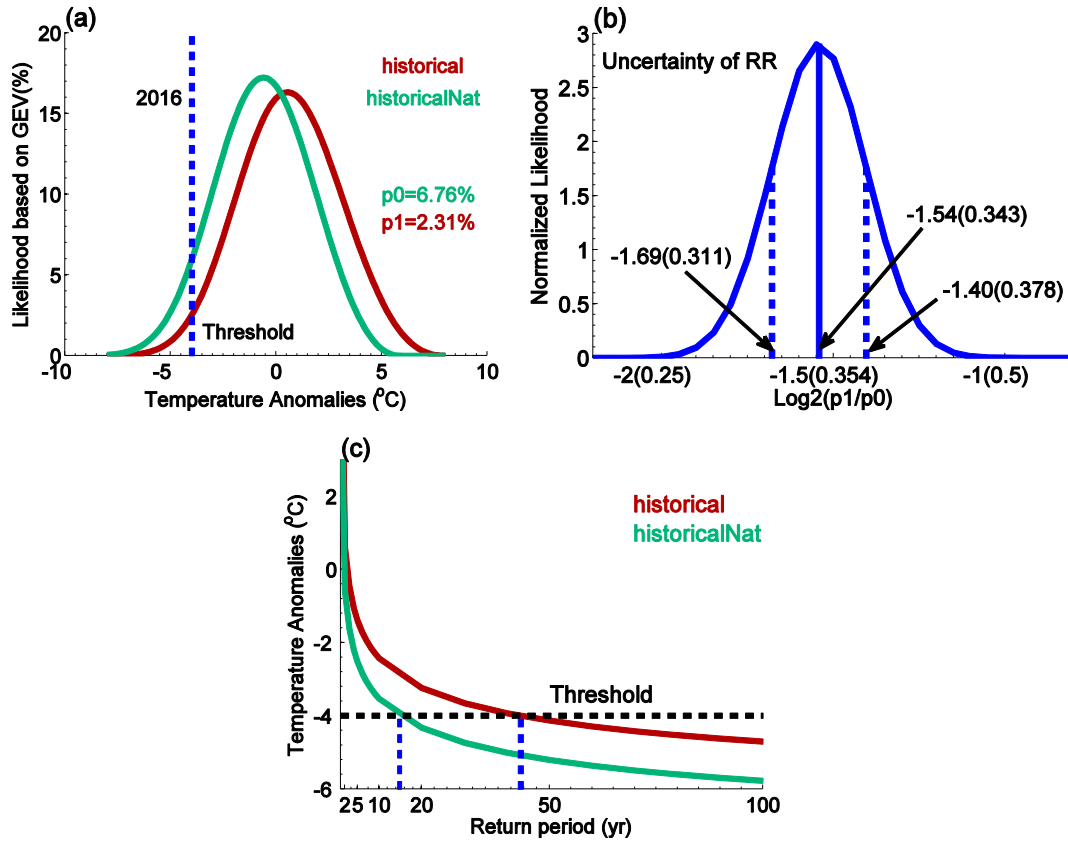


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